There was more than one method to solve this problem. The first would be to attempt a linear fit of the form y=mx+b off of the chart and then plot (one would have to transform the y axis to something linear first). This presents serious accuracy problems in the fact that reading enough accurate data points off the figure would be inaccurate and time consuming. The second method would be to use the formulas listed in the text and plot them directly in excel or matlab or mathcad. The trouble with this method is that doing this properly could take some time as there are many constants that could be mis-entered in causing errors. The other problem with this is that sometimes the constants given for effective mass or bandgap differ from what was used when the chart was created. A third method would be to notice that ni for SI and GaAs is given for one temperature, 300k and then notice that ni varies with temperature to scale the 300K ni value appropriately.

$$ni\_300K := 9.65 \cdot 10^{10} cm^{-3}$$

$$E_g := 1.12459V \qquad q := 1.6 \cdot 10^{-19} C$$

$$T := 300K$$

$$k := 1.380066 \cdot 10^{-23} \frac{J}{K}$$

$$n_i := ni\_300K \cdot \frac{T^{1.5}}{(300K)^{1.5}} \cdot \frac{e^{\left(-E_g \cdot \frac{q}{2k \cdot T}\right)}}{e^{\left(-E_g \cdot \frac{q}{2k \cdot 300K}\right)}} \qquad n_i = 9.65 \times 10^{10} cm^{-3}$$

Now one question might be is that did this graph take into account the fact that Eg varies with temperature? I order to dot hat one had to read reference 5 and find that the authors used this equation:

$$n_i := 3.1 \cdot 10^{16} \frac{cm^{-3}}{K^{1.5}} \cdot T^{1.5} \cdot e^{\left(-.603V \cdot \frac{q}{k \cdot T}\right)} \qquad n_i = 1.221 \times 10^{10} cm^{-3}$$

Notice that this gives a different value of ni at 300K.

One could also use the bandgap vs. temperature equation found in the text to modify Eg and then use the scaling method.

Three different methods are used in Figure 1. Series one represents the "scaling method" with no Band gap dependence on temperature. Series two represents the scaling method that includes temperature dependence on the band gap. Series three represents the equation cited in the text. Notice how the ni for the two series that take into account variances in bandgap are closer than the one that does not? Looking at the graph it sees that the text does not use a bandgap dependence model, but clearly the reference did!

Lesson learned: All ways check your references when trying to repeat another's work!

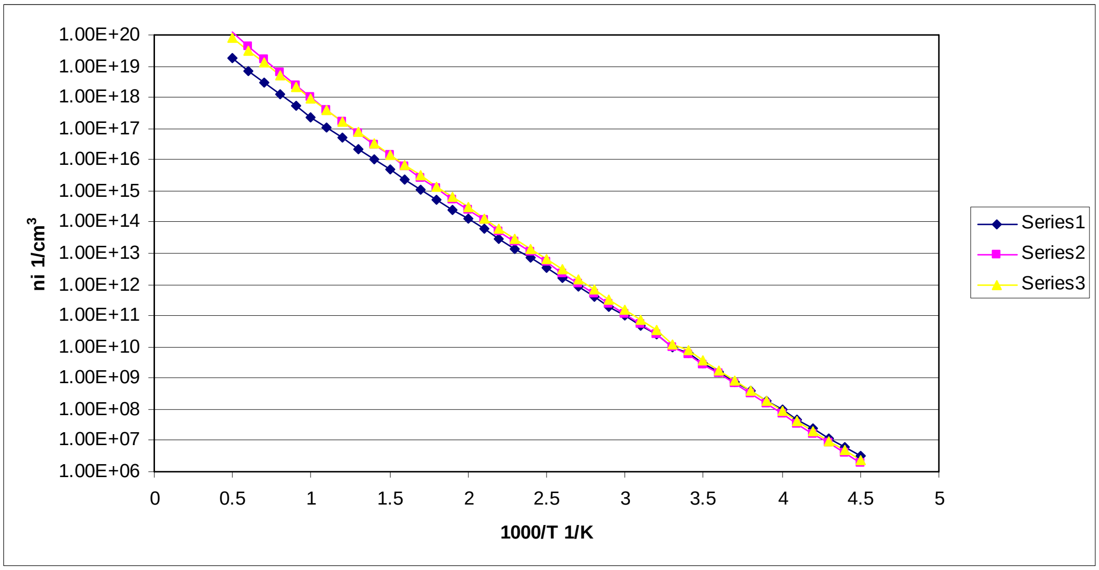


Figure 1: Ni vs. Temperature for three different methods.

Here is the plot for GaAs. Note: The Bandgap dependence was taken into consideration according to problem 8 in chapter 2 of the text.

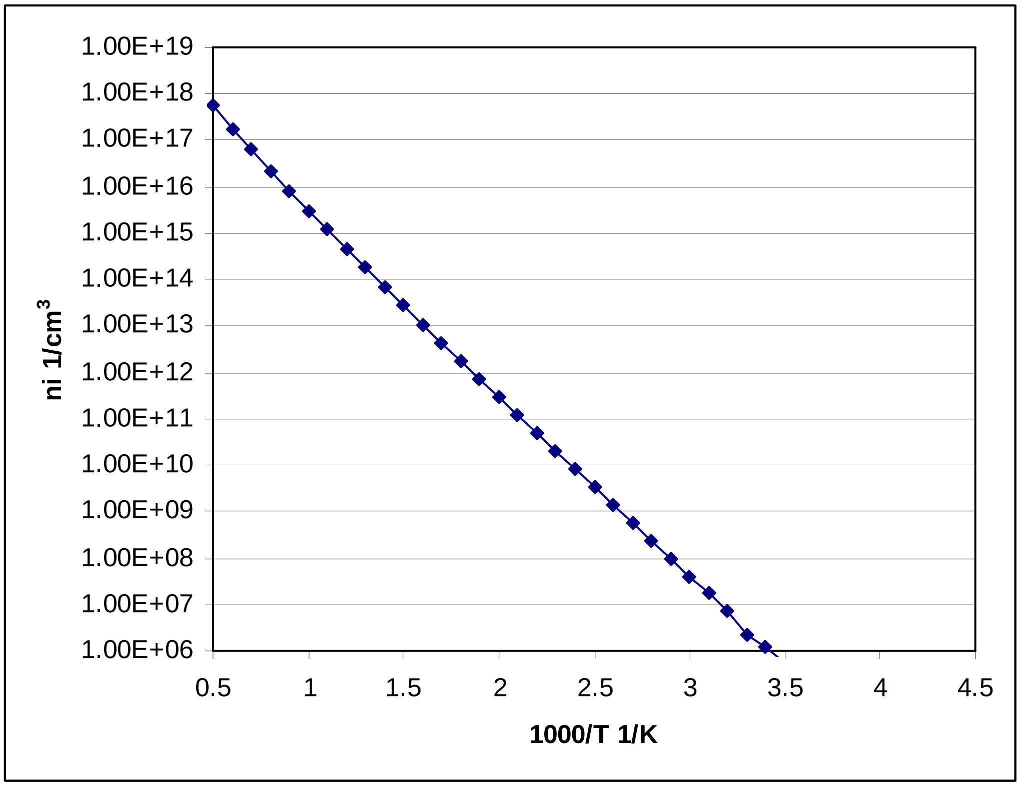


Figure 2: Ni vs. Temperature for GaAs.

What is the band gap of Silicon at 700^{o}C? From problem 8 in the text or reference 5 from the text:

$$Temp := 700 + 273$$

$$E_{g\_Si} := 1.17 - \frac{4.73 \cdot 10^{-4} \cdot Temp^2}{Temp + 636} \qquad E_{g\_Si} = 0.892$$

What is the band gap of GaAs at 700^{o}C? From problem 8 in the text or reference 5 from the text:

$$Temp := 700 + 273$$

$$E_{g\_GaAs} := 1.519 - \frac{5.405 \cdot 10^{-4} \cdot Temp^2}{Temp + 204} \qquad E_{g\_GaAs} = 1.084$$

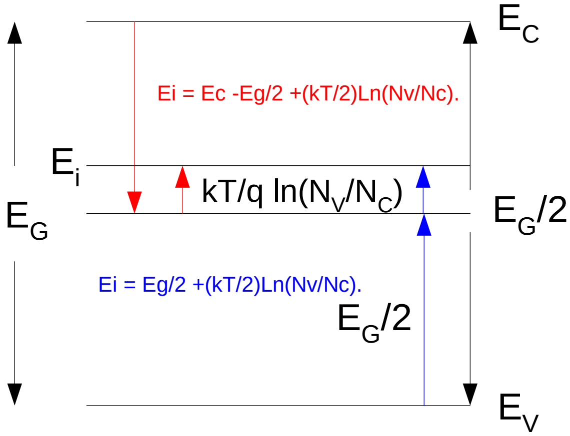
To recreate Figure 28 from chapter 2 of the text we need the Bandgap as a function of temperature, NC and NV as a function of temperature.

$$N_C := 2.86 \times 10^{19} \cdot \frac{T^{1.5}}{(300K)^{1.5}} \qquad N_C = 2.86 \times 10^{19}$$

$$N_V := 2.66 \cdot 10^{19} \cdot \frac{T^{1.5}}{(300K)^{1.5}} \qquad N_V = 2.66 \times 10^{19}$$

$$E_i := \frac{E_g}{2} + \frac{k \cdot T}{2 \cdot q} \cdot \ln\left(\frac{N_V}{N_C}\right) \qquad E_i = 0.561\ V$$

I vary slightly from the book on the definition of Ei. I take it from the valence band. Looking at the figure below you see that it come out to the same position.



$$\text{Temp} := 600$$

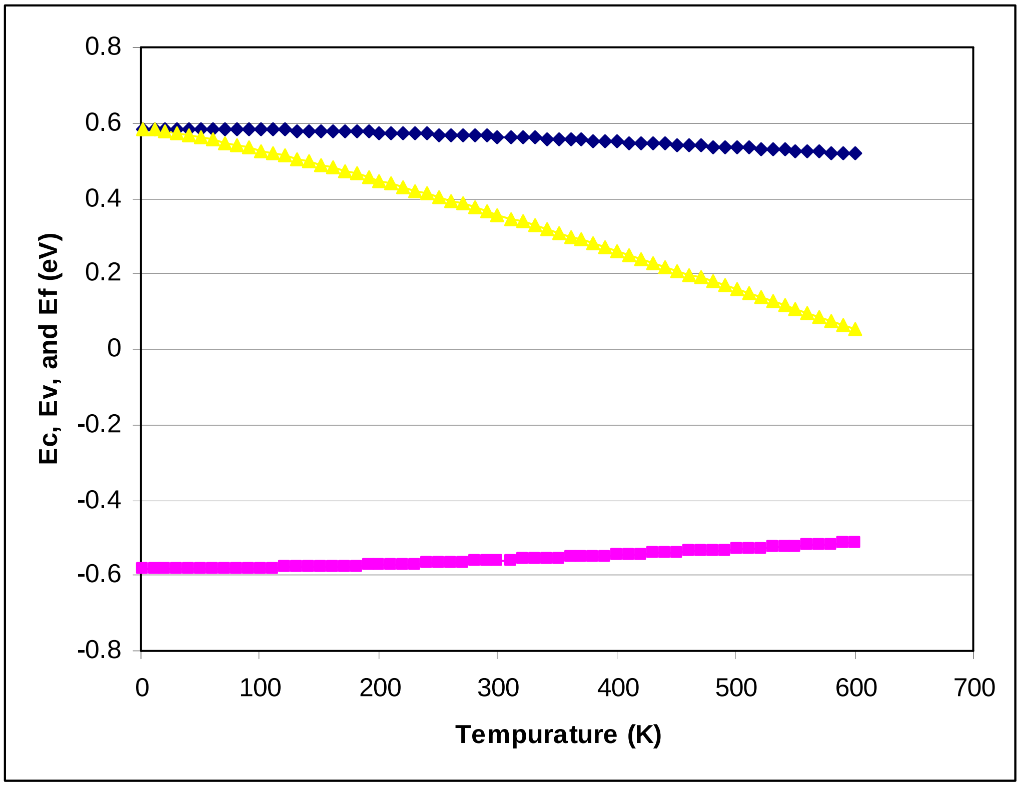
$$E_{go} := 1.17 \qquad \alpha := 4.73 \cdot 10^{-4} \qquad \beta := 636$$

$$E_g := E_{go} - \frac{\alpha \cdot \text{Temp}^2}{\text{Temp} + \beta} \qquad E_g = 1.032$$

In the plot Ei is given as zero or the reference point. This means we have to find EC as Eg-Ei, and EV as -Ei. This plot assumes complete ionization of the impurities. Below 100K this is not true according to figure 29 of the textbook. If you look closely at figure 28 in the text Ef is not really plotted below 100K.

$$E_C := E_g - E_i \qquad N_D := 10^{16}$$

$$E_F := E_C - \frac{k \cdot T}{q} \cdot \ln\left(\frac{N_C}{N_D}\right)$$



It seems to match pretty well except that the absolute value of the conduction band and the valence band at 0K seem to be greater than .6eV. Given that the equation used for bandgap gives a maximum bandgap for SI at 0K of 1.17eV, these values can never exceed .6eV. Someone could have used different values. It would take to long too get the reference cited for a homework, as the reference was a text, and IIL takes two weeks.